INSTRUCTOR'S MANUAL

BIOLOGY

THIRD EDITION

JOHN W. KIMBALL
Tufts University

ADDISON-WESLEY PUBLISHING COMPANY
READING, MASSACHUSETTS • MENLO PARK, CALIFORNIA
LONDON • AMSTERDAM • DON MILLS, ONTARIO • SYDNEY

Cover photo: Fronds of *Cycas revoluta,* one of the most primitive seed-bearing plants. (From Peter S. Stevens, *Patterns in Nature,* Little-Brown and Company, 1974.)

This book is in the
ADDISON–WESLEY SERIES IN BIOLOGY
Harper Follansbee, Consulting Editor

ISBN 0-201-03617-7
ABCDEFGHIJ-AL-798765

PREFACE

This guide is, in general, organized according to the following pattern. For each chapter in the textbook, a few introductory comments are given where they might be helpful. Any questions appearing within the body of the chapter are indicated and appropriate answers given. Mention is made when particular lecture demonstrations or displays, movies and film loops might serve to reinforce the material of the chapter. Particular emphasis is given to the listing of film loops. In recent years, many teachers have found that these short, easily-manipulated single-concept films are an ideal medium with which to present biological phenomena that cannot be easily demonstrated in lecture or examined in the laboratory.

Most of the film loops that are mentioned in this manual can be secured from BFA Educational Media, 2211 Michigan Avenue, Santa Monica, California 90404, and their catalog number is given.

Laboratory exercises are also suggested for each chapter, but no attempt has been made here to give detailed instructions for them. In many cases, these can be found in one or another of the laboratory manuals already available. However, specific reference is made to the exercises appearing in my *Biology: a Laboratory Introduction*, published by Addison-Wesley in 1967. This laboratory manual was specifically designed to accompany the textbook.

Suggested answers to the Exercises and Problems at the end of each chapter are given following the material described above.

The list of references given for each chapter in the textbook is not intended to be exhaustive. Other things being equal, the books and articles were selected with an eye to easy availability and inexpensiveness. The order of references is approximately the same as the order of the related topics within the chapter. The brief description accompanying many of the references is designed to aid the student in selecting those that will meet his purposes.

Any suggestions for the improvement of either the textbook or this guide will be welcomed.

April, 1975 J.W.K.

'ONTENTS

'ART I. THE CHARACTERISTICS OF LIFE

ıapter 1. Introduction

The purpose of this chapter is simply to set the stage for what follows. There are her ways to define life, but the one used here gives the framework of the entire book. A riety of living specimens, including a small mammal (e.g. rat) in a simple metabolism cham-ɪr, can be used to illustrate some of the characteristics described. Laboratory work at this ›int might include training in the use of the microscope, including the preparation of wet ounts. Detailed instructions can be found in Exercise 1 of *Biology, A Laboratory Intro-ıction,* the manual designed to accompany this text (Addison-Wesley, 1967).

ıswers to Exercises and Problems

. Yes. It exchanges materials with its surroundings and it responds to certain changes (e.g., a puff of air) in its environment. No.

. They are similar in that both of them involve the duplication of the pattern of the organism. They are different in that new individuals are formed in the second case but not in the first.

. Organisms cannot grow unless they take in materials from the environment and transform these into their pattern. Metabolism includes the exchange and transformation of materials.

. Most organisms (plants as well as animals) satisfy their metabolic needs by responding to certain stimuli in their environment. In turn, this responsiveness is dependent upon the energy and/or substances produced during metabolism.

. Sexual reproduction involves two parents and a recombination of hereditary traits. Asexual reproduction involves only one parent and no recombination of hereditary traits.

. No. Yes.

. A change in the environment which can be detected.

. There are many examples that the student may cite, especially in medicine and agriculture.

Chapter 2. The Study of Life

The purpose of this chapter is to introduce the student to some of the ways in wh
a biological problem can be examined – done here through the use of a case study: the
problem of nitrogen fixation. It is to be hoped that this approach will also ease the trans
tion into the difficult material of the next two chapters.

ART II. THE ORGANIZATION OF LIFE

The purpose of this section is to reveal the structure of living organisms at several
vels, starting with atomic particles and ending with tissues. A detailed examination of
ganization at the organ, system, and population levels occurs in other parts of the book.
ne student should be encouraged to keep each level of organization in its proper perspec-
ve as part of the whole picture of the organization of living things.

napter 3. The Chemical Basis of Life: Principles

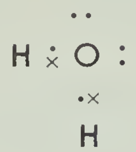
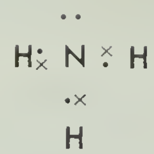
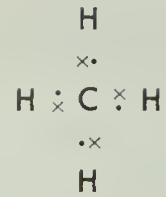
The time devoted to the material of this chapter will depend somewhat upon the back-
ound of the students. The periodic table is included simply for reference.

The answer to the question on p. 29 is **32**. On p. 30, the use of C-12 as a standard of
omic weight gives hydrogen an atomic weight of 1 because there is simply one proton in its
icleus. On page 31, the molecular weights are: $CO_2 = 44$. The formula for aluminum
loride (p. 35) is $AlCl_3$. The reason a 1% solution of NaCl (p. 38) would contain almost
lf again as many ions as a 1% solution of KCl is that the sodium ions are so much lighter
an the potassium ions.

Exercise 4 of the laboratory manual is designed to accompany this chapter. It intro-
ices the student to: (1) the metric system of measurement; (2) certain basic laboratory
ocedures such as the use of the balance, volumetric flask, pipette, and burette; (3) the
iantitative relationship that exists between the reacting substances in a chemical change;
d (4) the nature of acids, bases, and the pH scale.

nswers to Exercises and Problems

. (a) Oxygen, (b) Water, (d) Glucose.
2. An ion is an electrically charged atom or group of atoms.
3. H^+.
4. 16 gm.
5. Na, K.

6. (a)  (b)  (c)  (d) 

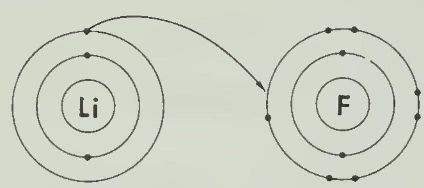
7. Compounds cannot be separated into their components by mechanical means, do r show the same properties as the substances of which they are composed, and have these substances present in definite proportions by weight. Mixtures do not meet these criteria.

8. Organic compounds contain carbon; inorganic compounds do not (with a few exce tions like $NaHCO_3$).

9. (a) Hydrogen, (c) Sodium, (e) Calcium, (f) Carbon.

10. C_2H_6. ($C_1H_3 = 15$; $\frac{30}{15} = 2$; $\therefore C_2H_6$.)

11.



12. 0.8 gm. A mole of Na(23) O(16) H(1) = 40 gm.

$$40\,(0.1)\quad \frac{200 \text{ ml}}{1000 \text{ ml}} \quad = 0.8 \text{ gm.}$$

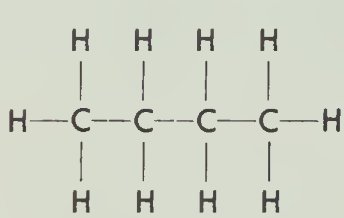
13. 60 gm.

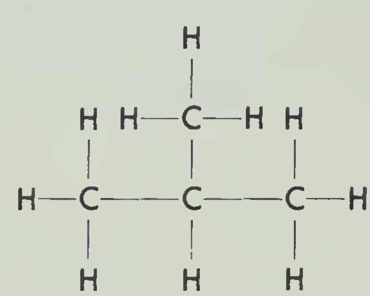
14. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$.

15. 100 ml. [$(0.2)(200) = 0.4x$.]

16. Aluminum.

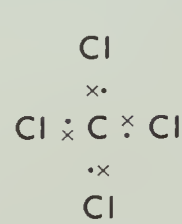
17. 37.5°C. ($98.6 - 32 = \frac{9}{5}$°C)

18. 

19. 

20. Isomers.

21. Electron: single negative charge, virtually no mass, generally outside the nucleus.
Proton: single positive charge, a mass weighing 1 AWU, in the nucleus.
Neutron: no charge, a mass weighing 1 AWU, in the nucleus.

22. 

3. Isomers are molecules with the same molecular formula but different structural formulas. Isotopes are atoms with the same number of electrons and protons (hence chemical properties) but a different number of neutrons.

hapter 4. The Chemical Basis of Life: The Molecules of Life

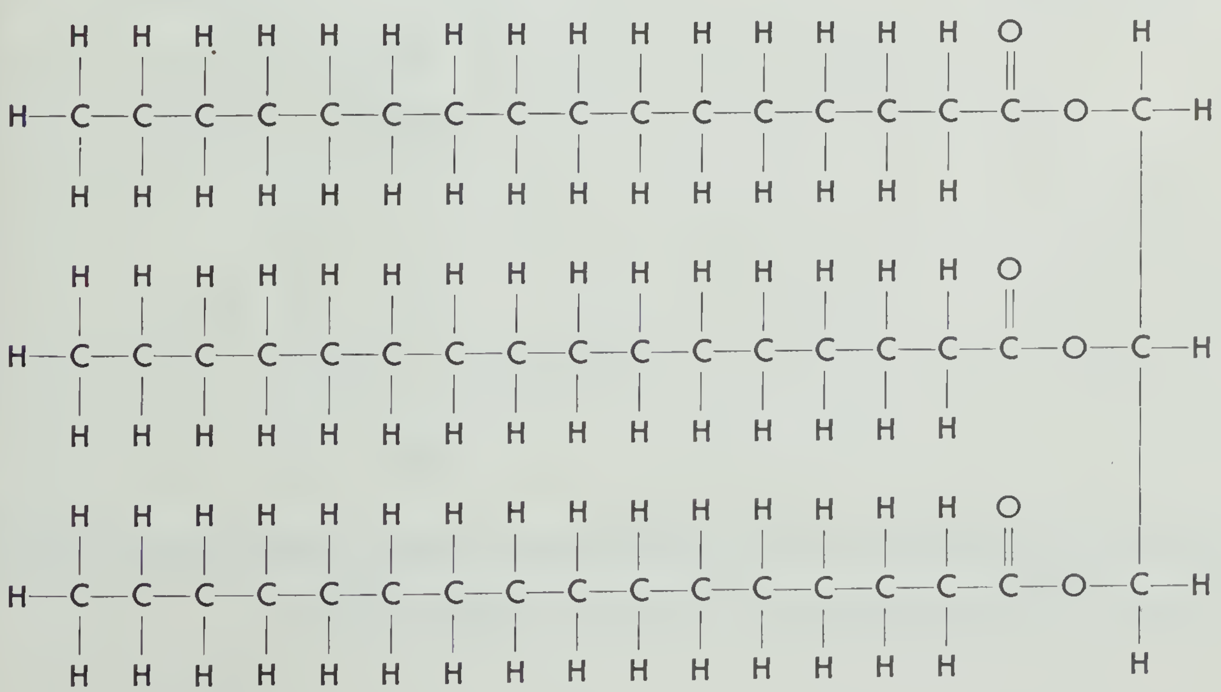
The emphasis in this chapter is on the major categories of organic molecules found in ving things.

The molecular formula of sucrose (p. 52) is also $C_{12}H_{22}O_{11}$. On p. 59, the supporting xtracellular material in plants is cellulose. Any hydrolysis can serve as an example of a hemical reaction in which water is a reactant (p. 65).

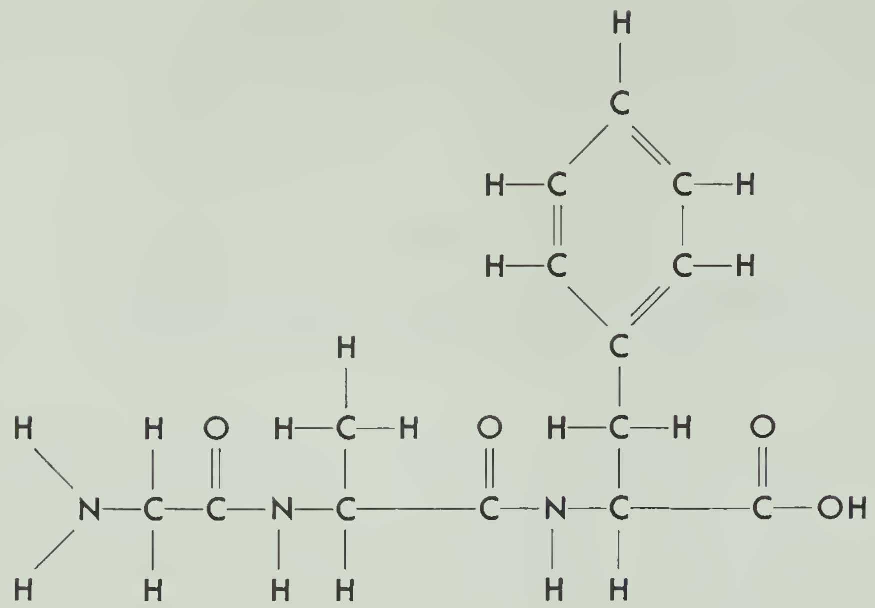
Laboratory work can include qualitative tests for the major organic molecules (e.g. reucing sugars, starches, proteins, fats) both on pure samples and in the cells of such tissues examined microscopically) as apple, potato, bean, and nut (e.g. pecan) parenchyma. Deiled instructions are provided in Exercise 5 of the laboratory manual.

nswers to Exercises and Problems

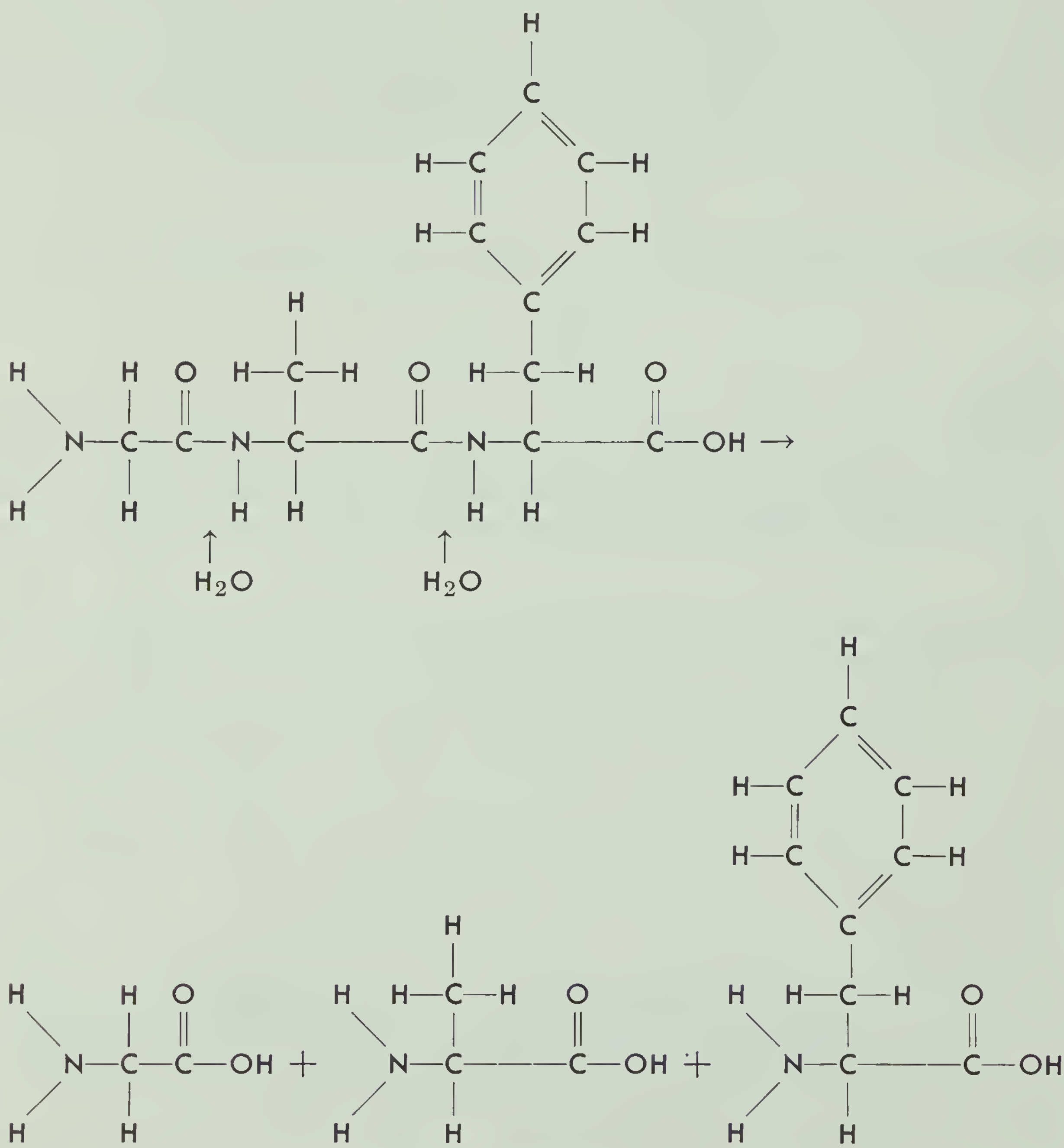
1. Fats.
2. Nitrogen.
3. A medium for chemical reactions, a participant in many chemical reactions, a catalyst for many chemical reactions, unusual heat capacity, liquid over most of the range of common terrestrial temperatures, and with the solid form (ice) less dense than the liquid.
4. An organic compound, not used as a fuel or structural material, which the organism cannot synthesize from the carbohydrates, fats, and proteins in its diet.
5. Ribose instead of deoxyribose, uracil instead of thymine, and usually single-stranded.
6.



7.



8.



9. Saturated fats contain no double bonds between carbon atoms; unsaturated fats do

10. Of glucose: fructose, galactose. Of sucrose: maltose, lactose.

apter 5. The Cellular Basis of Life

Laboratory work to accompany this chapter is described in Exercise 6 of the labora-ry manual. It includes the examination of onion epidermal and parenchyma cells, *Ana-aris (Elodea)* cells displaying cyclosis, cheek cells, and the sperm cells of a frog.

nswers to Exercises and Problems

. Plant cells have a cellulose wall, plastids (generally), and no centrioles.

. Cell membrane, nuclear membrane, endoplasmic reticulum, Golgi complex, vacuolar membranes, mitochondria, lysosome.

. Advantages: increased efficiency at coping with the environment; often, increased size.
Disadvantages: interdependence of parts which often leads to aging and death; necessity for "supporting" systems (e.g., circulatory) for internal tissues.

. An organism is a single living being. An organ is a group of anatomically and functionally related tissues which perform one or more specific roles in the organism.

. The surface areas are proportional to the squares of the diameters.

			Ratio
Mycoplasma:	$d \cong 0.1\ \mu m$,	$d^2 = 0.01$	1
Staphylococcus:	$d \cong 1\ \mu m$,	$d^2 = 1$	100
Cheek cell:	$d \cong 60\ \mu m$,	$d^2 = 3600$	360,000

. The volumes are proportional to the cubes of the radii (or diameters).

			Ratio
Mycoplasma:	$d \cong 0.1\ \mu m$,	$d^3 = 0.001$	1
Staphylococcus:	$d \cong 1\ \mu m$,	$d^3 = 1$	1,000
Cheek cell:	$d \cong 60\ \mu m$,	$d^3 = 216{,}000$	216,000,000

. (a) Cell wall: cellulose, (b) Chromosome: DNA, protein,
(c) Ribosome: RNA, protein, (d) Cell membrane: protein, lipid,
(e) Lysosome: protein, (f) Oil droplet: fat.

PART III. METABOLISM

The theme of Part III is the exchange of materials between a cell and its environme the transformation of these materials within cells, and the exchange of these materials between multicellular organisms and their external environment.

Chapter 6. The Metabolism of Cells

The idea that all cells are surrounded by a liquid whose chemical and physical prop erties must be maintained within certain limits should help the student grasp the importa of the various regulatory mechanisms of multicellular organisms to be discussed in later chapters.

On p. 108, the reason that larger objects do not exhibit Brownian motion is becaus their inertia is too great for them to recoil from collisions with water molecules.

Demonstrations of Brownian motion, and some form of osmometer should be presented. The film loop *Amoeba proteus* (Ealing #81-5019) shows the action of the contra tile vacuole as well as feeding, cytoplasmic streaming, and pseudopod formation. In the laboratory, the students can study the effect of pH or temperature on enzyme activity, e pepsin and/or trypsin on cooked egg white (Fig. 7.9); salivary amylase or diastase on star Exercise 7 of the laboratory manual provides detailed instructions and data sheets for de mining the effect of temperature on the action of salivary amylase.

Answers to Exercises and Problems

1. Diffusion, active transport, pinocytosis.
2. The column will begin to fall as the slow diffusion of sugar molecules across the cellophane membrane continues.
3. A 1-molar solution of salt because approximately twice as many particles are prese ($NaCl \rightarrow Na^+ + Cl^-$).
4. 20 million.
5. (a) Red blood corpuscles would burst.
   (b) Plant cells would become turgid.
   (c) Amoeba's contractile vacuole would operate steadily.

The effect in each case occurs because distilled water is hypotonic to cytoplasm and so water enters the cells by osmosis. The red blood corpuscles have no cell wall to resist the increase in pressure that results. The amoeba has no cell wall either but pumps out the excess water with its contractile vacuole.

6. (a) Red blood corpuscles would shrink.
   (b) Plant cells would become plasmolyzed.
   The effect in each case occurs because the sea water is hypertonic to cytoplasm and so water leaves the cells by osmosis.
7. Its contractile vacuole would cease to operate.
8. Yes. Although the likelihood of collisions is the same in all directions, the property of randomly-moving objects to move away from their starting point would result in both gases diffusing throughout the room.

hapter 7. Heterotrophic Nutrition

The film loop *Amoeba proteus,* mentioned above, is also appropriate for this chapter. *ydra* (Ealing #81-5761) includes remarkable views of feeding by this organism.

Exercise 8 of the laboratory manual introduces the student to the gross anatomy (and little of the histology) of the digestive system of the frog.

The ultimate source of the organic molecules mentioned on p. 125 is photosynthesis.

nswers to Exercises and Problems

1. Protein:

   $\left.\begin{array}{l}\text{pepsin (stomach),}\\ \text{trypsin, chymotrypsin (pancreas)}\end{array}\right\}$ protein → peptides
   carboxypeptidase (pancreas): peptides → amino acids
   aminopeptidases, tripeptidase, dipeptidases (intestine): peptides → amino acids

   Fat: lipase (pancreas) (aided by emulsifying action of bile): fats → fatty acids + glycerol

   Starch:

   salivary amylase (mouth): starch → maltose
   pancreatic amylase: starch → maltose
   maltase (intestine): maltose → glucose

2. The chief function of the large intestine in terrestrial vertebrates is the reclaiming o water from the intestinal contents. In a hypotonic environment, the continuous diffusion of water *into* the animal has not provided any survival advantage to havin a large intestine.
3. Diffusion, active transport, endocytosis.
4. No. Macromolecules (e.g., glycogen) stored within cells are digested there for use within the cell or release from the cell (as in the liver).
5. Chewing increases the food surface exposed to the action of the digestive enzymes.
6. By fusing lysosomes and food vacuoles. Thus its digestive enzymes are kept separat by a membrane from the "ground substance" of the cell.
7. By depositing the enzymes within the spaces of the endoplasmic reticulum, they ar kept separated by a membrane from the "ground substance" of the cell.
8. Sucrase is an enzyme that hydrolyzes sucrose into glucose and fructose.
9. No. The density of small organisms in the air is not sufficiently great to enable animals to secure food by filtering air.

Chapter 8. Energy Pathways in the Cell

Each teacher will want to use his own judgment as to how much of the detail in thi chapter is appropriate for his students to memorize. In my experience, the students gain a better appreciation of the whole process *after* they have made the effort to trace it thro step-by-step, accounting for every atom. But when they have done this, I require that the *remember* simply the general outline of the process (dehydrogenation, decarboxylation, electron transport, cytochromes, phosphorylation, etc.); its significance (Section 8.6), bu *not* every intermediate compound.

On p. 150, one less ATP is produced when flavin donates electrons to the cytochro system because the first phosphorylation in the chain is by-passed. The oxaloacetic acid then unites with another molecule of acetic acid ($C_2H_4O_2$).

A rat (or mouse or bees, etc.) in a jar containing some soda lime, and stoppered wit a rubber stopper from which a volumetric pipette (containing a soap film) projects, can h its oxygen consumption measured quickly and easily. It is particularly instructive to mea O_2 consumption with reference to the surface area ($1/m^2/hr$) of each of the animals stud Complete instructions for doing this (with a laboratory rat) are provided in Exercise 9 of the laboratory manual. This exercise also includes a table of average human metabolic rat using the same units.

nswers to Exercises and Problems

1. Fats.
2. In both cases, glucose is a reactant, carbon dioxide is a product, and energy (ATP) is produced. Several intermediates are the same in both processes and NAD is the REDOX agent.
3. Fermentation is anaerobic, inefficient, and produces toxic alcohol rather than water.
4. Both processes require a starch which is hydrolyzed to glucose which is fermented by yeast. In the case of breadmaking, only some of the starch is hydrolyzed, the mixture is thick, and the carbon dioxide is the useful product. In brewing, the mixture is watery and the alcohol is desired as well.
5. NAD, flavin, cytochromes, oxygen, dehydrogenases, as well as the substrates used in cellular respiration.
6. The chemical energy stored in organic molecules can be measured most easily by calorimetry; that is, converting it into heat by burning completely in pure oxygen. The quantity of heat produced is measured in calories.
7. 12 ($6O_2 \times 2$). 12 ($6CO_2 \times 2$).
8. 1 (12/12).
9. The ratio becomes larger: that is, greater than 1. For example,

$$2C_{57}H_{110}O_6 + 163O_2 \rightarrow 114CO_2 + 110H_2O; \ \tfrac{163}{114} = 1.43.$$

0. Yeasts carry on cellular respiration if oxygen is available and produce no alcohol in doing so.
1. 46 gm.

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2\,CO_2$$

$$\frac{180}{90} \qquad \frac{2 \times 46}{46} \qquad \frac{2 \times 44}{44}$$

0.5 mole (90 gm) glucose produces 1 mole (46 gm) of ethanol.

2. 37. (Glucose phosphate produced with inorganic phosphate rather than ATP, thus increasing the net yield of ATP by one.)

hapter 9. Photosynthesis: Trapping the Sun's Energy

The material in this chapter should be related closely to Chapter 10, especially with spect to the photolysis and synthesis of water, electron transport (REDOX), phospholation, and the pigments involved in photosynthesis and respiration. Also the historical pproach in this chapter should help the student see how each discovery in science depends pon the work of the past.

On p. 159 the connection between using energy to respond to the environment and using energy to preserve the integrity of molecular and cellular organization is that the latt depends upon the organic molecules (food) detected in the environment and successfully consumed. On p. 180 the chemoautotrophic sulfur bacteria use more H_2S in the producti of a molecule of glucose than the photosynthetic sulfur bacteria do, because they use H_2S not only for the formation of $NADH_2$ to reduce carbon dioxide but also for the formatio of ATP by oxidation.

The photoreduction of thionine provides a dramatic demonstration. (10 ml of 0.001 M thionine plus 10 ml 6N H_2SO_4, diluted to 500 ml; plus 2g $FeSO_4 \cdot 7H_2O$. Use photoflood lamp.) The details of the process can be found in Heidt, L. J., "The Photochemical Reduction of Thionine," *Journal of Chemical Education*, **26**, 525, October, 194 The fluorescence and absorption spectrum of a chlorophyll solution should also be demonstrated.

The effects of light intensity, CO_2 concentration, and temperature on the rate of O_2 evolution by a sprig of *Anacharis* (*Elodea*) can be investigated in the laboratory. Figu 9.9 shows one technique for doing this.

We have, however, secured the best results using leaf disks impregnated with a $NaHCO_3$-containing buffer as described by Wickliff, J. L. and R. M. Chasson, "Measurement of photosynthesis in plant tissues using bicarbonate solutions," *BioScience*, **14**, No. 32–33, March, 1964. Instructions adapting this technique for the elementary laboratory are given in Exercise 10 of the laboratory manual. The process is also illustrated in the fil loop *Measuring Rate of Photosynthesis* (Ealing #81-5639). If time is available, this relatively simple and reliable technique can be used to study a number of other factors that might affect the rate of photosynthesis.

Answers to Exercises and Problems

1. H_2O.
2. It provides additional evidence that two separate light reactions are involved in phot synthesis each operating through its own pigment (with maximal light absorption about 45 nm apart).
3. All life depends upon the autotrophic organisms, the only creatures that can make food (carbon compounds) from inorganic materials or, more broadly, accomplish a transfer of electrons from strongly electronegative atoms (e.g. oxygen) to weakly el tronegative ones (e.g. carbon). Most autotrophs use the energy of sunlight to raise t energy level of electrons sufficiently for this to be done. A few, the chemoautotrop use the energy acquired by carrying out an oxidation on their substrate (with electrons going from higher to lower energy levels) to accomplish the reverse process, th is, to raise the energy level of other electrons in the reduction of carbon.

   By respiration (or, with much less efficiency, fermentation) all organisms gain energy with which to carry out their life activities by letting the electrons in their fc (carbon compounds) return to more strongly electronegative atoms (usually oxygen Some of the energy released as these electrons pass from higher to lower energy leve is trapped, usually in the form of ATP.

4. Autotroph: organism that manufactures its food from inorganic raw materials. Heterotroph: organism that depends upon organic molecules secured from its environment.

5. NAD

6. Green.

7. No. At excessively high temperatures, enzyme action will decrease because of denaturation of the protein portion of the enzyme molecules.

8. No. At excessively high concentrations of CO_2, the resulting low pH ($CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$) would reduce enzyme action.

9. Temperature. Unless the water flow is regulated carefully, the heat of the lamp will warm the plant and the rate of the dark reactions will be increased.

0. After a period of time, the CO_2 content of the solution will be depleted and the rate of the dark reactions will be diminished.

1.

	Photosynthesis	Respiration
(a)	$6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O.$	$C_6H_{12}O_6 + 6O_2 + 6H_2O \rightarrow 6CO_2 + 12H_2O.$
(b)	Removes electrons from water and attaches them to carbon.	Removes electrons from carbon and attaches them to oxygen to form water.
(c)	Initial step accomplished by Mg-containing porphyrin = chlorophyll.	Ultimate step accomplished by Fe-containing porphyrin = heme.
(d)	Stores 690,000 calories per mole of glucose.	Releases 690,000 calories per mole of glucose.
(e)	Supplies materials for respiration.	Supplies materials for photosythesis.
(f)	Constructive (anabolic).	Destructive (catabolic).

2. Yes. To digest macromolecules (e.g. starch) stored within their cells for transport (as sugars) to other parts of the plant.

3. 4.

4. 4. 2. 3.

5. 2. Although these 4 electrons will produce the $NADH_2$ needed to reduce one molecule of CO_2, one additional molecule of ATP is needed (question 14). Hence the inadequacy of noncyclic photophosphorylation alone to meet the needs of the dark reactions.

Chapter 10. Energy Flow Through the Biosphere

A number of films are available (Encyclopaedia Britannica Films, Inc.) that illustrat the various terrestrial and marine biomes. These include: *The Tropical Rain Forest, The Temperate Deciduous Forest, The High Arctic Biome, The Grasslands, The Desert,* and *The Sea. Succession – From Sand Dune to Forest* (Encyclopaedia Britannica Films, Inc.) provides a clear and thorough description of sand dune succession on the southern shore Lake Michigan.

Answers to Exercises and Problems

1. (a), (b), (c), and (d).
2. Decomposer.
3. Autotroph (producer).
4. (a) Hibernation. (b) Sheds leaves, stores food in roots. (c) Migrates south. (d) Die Only the seeds remain viable. (e) Aboveground portion (leaves) dies. Food stored underground stem. (f) Leaves die. Underground stem with food reserves remains alive. (g) Lives in sheltered spot using food reserves laid down during summer and (h) Leaves die. Food stored in fleshy root which along with small stem remains ali below ground. (i) Sleeps in sheltered location. (j) Remains below ice. (k) Leaves a aboveground stem die. Underground stem with food and meristems (the tuber) remains alive. (l) Remain in hive living on honey stores. (m) Either eggs, embryos, la (various stages), pupae, or adults–depending on the species–pass the winter in a dc mant condition.
5. Fleshy stem (water storage), spines (protection from predation), recessed stomata, heavy cuticle, and no (or small) leaves (reduced transpiration), shallow, usually fib root system (picks up rainwater quickly and efficiently).

Chapter 11. Materials Cycles

Answers to Exercises and Problems

1. (a) Nitrogen-fixing: $N_2 \rightarrow$ organic nitrogen compounds.
   (b) Decay: organic nitrogen compounds $\rightarrow NH_3$.
   (c) Nitrifying: $NH_3 \rightarrow NO_3^-$.
   (d) Denitrifying: NO_3^- $(NO_2^-) \rightarrow N_2$.
2. 8%.
3. NO_3^- for protein synthesis. $PO_4^{\equiv}$ for nucleic acid synthesis as well as for energy tr fer (ATP and NAD).

4. Much of the organic matter produced by grasses is incorporated deeply and quite uniformly in the soil after death by decay of the extensive, fibrous root systems. Most of the organic matter produced by forests, in contrast, is deposited at the surface (e.g. fallen conifer needles) and is incorporated into a rather thin layer of topsoil. Furthermore, the dryness of grasslands soil, especially in the summer, seems to result in reduced breakdown of humus into inorganic constituents and reduced transport of minerals into (by definition) a subsoil layer. Other factors, such as terrain, may alter this picture somewhat.

hapter 12. Gas Exchange in Plants and Animals

In the laboratory, the structure (and closure) of stomata in a leaf (e.g., Calla lily) pidermis can be examined. If a Benedict-Roth respirometer is available, the metabolic rate f a student can be determined and compared with that of the rat, mouse, etc. which was etermined earlier (Chapter 8). If the equipment is available, the experiments illustrated in igs. 12.20, 12.21, and 12.22 can be carried out.

nswers to Exercises and Problems

1. Nostril → nasal cavity (turbinates) → nasopharynx → pharynx → glottis → larynx → trachea → bronchus → bronchioles → epithelial cell of alveolus → epithelial cell of capillary → plasma → RBC.
2. Reptiles: ribs; birds: air sacs; mammals: diaphragm.
3. They also use their skin for gas exchange.
4. Exhaled breath contains about 4% CO_2 which will aid in stimulating the victim's medulla oblongata.
5. Approximately 4700. $A = \pi r^2$; $d = 0.4$ mm; $r = 0.2$ mm $= 0.02$ cm; $r^2 = 0.0004$ cm^2, $\pi r^2 = 0.0013$ cm^2.

$$\frac{6}{0.0013} \cong 4700$$

6. The trees growing there are not adapted to waterlogged soil and their roots die of oxygen shortage.
7. Difficult to keep moist and while moist they and their filaments will tend to adhere to each other reducing the surface area exposed.
8. (c) 95% O_2, 5% CO_2.

Chapter 13. Transport in Animals

In answer to the question on p. 258, the pulmonary arteries and veins are exception in that they carry deoxygenated and oxygenated blood respectively. Increased blood pres- sure (p. 267) increases the rate of lymph formation because the filtration rate is increased whereas malnutrition increases the rate of lymph formation because the concentration of plasma proteins (hence, osmotic pressure) decreases.

Laboratory work for this chapter should include an examination of living and/or stained blood cells and examination of a vertebrate heart. A functioning capillary bed (e.g in web of frog foot) should be observed. The buffering and CO_2 capacity of the blood ca also be measured. Directions for these procedures are included in Exercise 11 of the labo tory manual. (The staining of blood cells is described in Exercise 23.)

Two outstanding film loops to use with this chapter are: *Circulation: Closed Transp Systems* (Ealing #81-5787), which shows the action of the heart and views of circulation the arteries, veins, and capillaries of a fish and a frog, and *Circulation: Open Transport Sy tems* (Ealing #81-5910) which shows the circulation in two arthropods and in a tunicate.

Answers to Exercises and Problems

1. To provide additional iron (Fe) for the synthesis of hemoglobin.
2. Calcium ions are essential to the clotting process and their removal permits collecte blood to be stored without its solidifying.
3. Capillary → venule → right subclavian vein → superior vena cava → right auricle → tricuspid valve → right ventricle → semilunar valve → pulmonary artery → arteriole → capillary → venule → pulmonary vein → left auricle → bicuspid valve → left ventricle semilunar valve → aorta → innominate artery → right subclavian artery → arteriole → capillary.
4. Reduced protein concentration of the plasma results in lowered osmotic pressure of the blood and the return of less lymph from the tissue spaces into the capillaries.
5. Because usually they disintegrate upon exposure to air and glass.
6. Arteries carry blood away from the heart, have thick muscular walls, and no valves. Veins carry blood to the heart, have thin, flabby walls, and have valves.
7. The pulmonary arteries.
8. Approximately 3200 liters. One liter of plasma releases 1.8 ml of O_2 to the tissues. Under strenuous exercise, tissues may need 5775 ml of O_2 each minute.

$$\frac{5775 \text{ ml}}{\frac{1.8 \text{ ml min}}{1}} = 3200 \text{ l/min}$$

9. Increased rate of heartbeat, increased volume of blood pumped at each heartbeat, emptying of blood reservoirs, opening of capillary beds in lungs and skeletal muscles, closing of capillary beds in viscera.

0. HbO_2 in RBC $\xrightarrow{\text{dissociation}}$ O_2 $\xrightarrow{\text{diffusion}}$ plasma $\xrightarrow[\text{capillary wall}]{\text{filtration through}}$ lymph in tissue space $\xrightarrow{\text{diffusion}}$ cell $\xrightarrow{\text{diffusion}}$ mitochondrion.

1. CO_2 in mitochondrion $\xrightarrow{\text{diffusion}}$ cytoplasm $\xrightarrow{\text{diffusion}}$ lymph of tissue space $\xrightarrow{\text{osmosis}}$ plasma of capillary $\xrightarrow{\text{diffusion}}$ RBC $\xrightarrow[\text{anhydrase}]{\text{carbonic}}$ $CO_2 + H_2O \rightarrow$

2. There is no appreciable hydrostatic pressure in the veins because of the pressure drop across the capillaries. The intermittent pressures of the muscle pump can be effective only if valves permit the blood to flow just toward the heart.

3. Both groups have an open circulatory system but the insects do not use theirs for the transport of gases; instead they use their tracheal system.

hapter 14. The Transport of Materials in the Vascular Plants

In answer to the question on p. 282, the basswood *(Tilia)* twig in Fig. 14.3 was four ears old when it was cut. A girdled tree (p. 286) will eventually die because no food can get own to the roots.

In the laboratory, the student should see sections of a root and of monocot and dicot ems (these may be prepared from fresh material on a hand microtome) as well as the external structure of a root tip (e.g. grass) and a woody dicot stem. Exercise 12 of the laboratory manual describes the procedures. It also includes directions for the preparation and amination of a leaf cross section and lower epidermis.

Pathways of Water in Woody Plants (Ealing #81-5506) gives a dramatic demonstration pporting the Dixon-Joly theory of water transport in the xylem. Another appropriate film op for this chapter is *Early Development of the Root System* (Ealing #81-5563).

nswers to Exercises and Problems

. Root hair → epidermal cell → cortex → endodermis (passage cell) → pericycle → xylem → stem → petiole → vein of leaf → palisade layer → spongy layer → phloem of vein → petiole → stem → root → pericycle → endodermis → cortex.

. There is little, if any, flow of fluid between the xylem and the phloem and thus the system is not truly *circulatory*. The composition of the fluid in the xylem and the phloem is markedly different. It does not participate in gas transport. There is no single pumping mechanism.

3. Root pressure. Guttation indicates that water is entering the leaf under pressure. Transpiration pull would not be effective on damp nights.
4. Anchorage of the tree. Absorption of water and minerals. Storage of food.
5. The root system was probably damaged during transplanting. Cutting off some of t branches reduces the area available for transpiration and helps bring the evaporative surface back into balance with the reduced area for water absorption.
6. The shift from narrow annual rings to wider ones suggests that several years of poor growth in the past were then followed by several years of good growth. Several sea- sons of ample rainfall following several dry seasons might account for this. Perhaps large trees surrounding the young elm had suddenly been removed, giving it greater posure to the sun.
7. The attraction between like molecules. The cohesion between water molecules ac- counts for the tensile strength of thin filaments of water and permits them to be lift great distances without the column snapping apart.
8. The attraction between unlike molecules. Adhesion between water molecules and t walls of xylem vessels and tracheids prevents the column of water from pulling away from the xylem walls when it is placed under the great tensions set up by transpirati pull.
9. It supplies food to nourish the sprouting flower and leaf buds.
10. Light, temperature, humidity, wind, and soil water, with most of these being inter- related.

Chapter 15. Excretion and Homeostasis

The chief weakness to the idea that gout has been associated only with brilliant men throughout history (p. 311) is that it is generally only such men for whom we have any medical records. The portal system previously studied (p. 311–312) is the hepatic portal system.

Exercise 13 of the laboratory manual provides detailed instructions for a study of kidney function in the laboratory rat. The procedure involves giving injections of NaCl, glucose, xylose (a reducing sugar that is neither reabsorbed nor excreted by the tubules) and phenol red (which is excreted by the tubules as well as filtered at the glomerulus), and then collecting the urine for chemical analysis.

Answers to Exercises and Problems

1. (a) Uric acid, (b) Urea, (c) Uric acid, (d) Urea.
2. (a) Nephridia, (b) Malpighian tubules, (c) Nephrons.

3. (a) Reabsorption in the tubules of just enough Cl^- to maintain homeostasis.
   (b) Failure to reabsorb most of the urea filtered at the glomerulus.
   (c) Tubular excretion of H^+ ions in exchange for Na^+ ions (if ECF is acid). Tubular excretion of HCO_3^- if the ECF is too alkaline.
4. Renal artery → afferent arteriole → glomerulus → Bowman's capsule → proximal tubule → loop of Henle → distal tubule → collecting duct → pelvis of kidney → ureter → bladder → urethra.
5. Yes, they simply do not shed them all at once.
6. (a) The same, (b) The same.
7. Proteins.
8. The ureter takes urine from the kidney to the bladder. The urethra takes urine from the bladder to the outside.
9. The liver.
0. Lower metabolic rate, fewer nitrogenous wastes, many products of metabolism can be used in photosynthesis.
1. (a) Contractile vacuole, (b) Kidneys, (c) Flame cells, (d) Kidneys, (e) Cell walls.
2. It is reduced. In a beaver, the quantity of urine formed would not change under these circumstances.
3. Excretion is the elimination of the wastes of cell metabolism while egestion is the elimination of materials that have entered a cavity or tube within the organism but have never participated in the metabolism of its cells.
4. They consume more proteins and thus deaminate more amino acids.
5. The reabsorption of salts in the tubules is markedly greater than the reabsorption of urea.
6. Kidneys, skin, lungs, and the liver.

PART IV. REPRODUCTION

Chapter 16. The Reproduction of Cells and Organisms

A film loop or movie of mitosis should be shown to impart a sense of the dynamics the process. One of the most remarkable of those available is *Mitosis–In Endosperm of Haemanthus katherinae* (Ealing #81-5340). The material was photographed through a d ferential interference microscope. The details of sexual and asexual reproduction in *Chla mydomonas* are shown vividly in *Chlamydomonas reinhardti–Reproduction and Life Cycle* (Ealing #81-5043).

Each student can examine for himself the various stages of mitosis by making a squ preparation of the meristem of an onion or broad bean (*Vicia faba*) root tip stained with acetocarmine or Feulgen solution. The procedure with the broad bean root tip is describ in Exercise 20 of the laboratory manual.

Answers to Exercises and Problems

1. Random assortment of maternal and paternal chromosomes during meiosis will pro- duce gametes that (with rare exceptions) contain a mixture of horse and donkey chromosomes and thus the complete hereditary blueprint of neither animal.
2. Occasionally, the random assortment of chromosomes during meiosis will produce a egg containing the complete haploid set of horse chromosomes. This egg, like that produced by a horse, can develop successfully following fertilization by either a hor or donkey sperm cell.
3. In mitosis, the chromosomes appear already duplicated, there is usually no synapsis nor crossing over, the centromeres become oriented directly on the equatorial plate and then the centromeres divide with the resulting separation of the duplicates of ea chromosome. In the first meiotic division, the chromosomes are not yet duplicated when they first appear, there is synapsis and crossing over, the centromeres become ented above and below the equatorial plate and there is no division of the centrome as the homologues separate. The first meiotic division generally takes much longer than a mitotic division.

4. In mitosis, each chromosome of the cell is duplicated (during interphase) and one member of each duplicate goes to each daughter cell. Thus, each daughter cell contains exactly the same hereditary blueprint as the parent cell. In meiosis, each cell (gamete or spore) produced contains an assortment of chromosomes virtually unique to it. This is because it (1) contains a random assortment of the maternal and paternal chromosomes of the parent cell and (2) many of these chromosomes contain portions of their homologue received by crossing over during synapsis. Thus each cell produced by meiosis contains (generally) a unique hereditary blueprint. When fertilization takes place with another cell produced by meiosis, the hereditary blueprint in the resulting zygote is altered still further.
5. (a) Glucose provides a source of energy and a source of carbon atoms for biochemical syntheses and thus growth.
   (b) $PO_4^{\equiv}$ ions are needed for the synthesis of nucleic acids.
   (c) $SO_4^{=}$ ions are needed for the synthesis of proteins.
   (d) N atoms are also needed for the synthesis of proteins, and nucleic acids. The metal ions are also used, e.g. in enzyme action.
6. No. If the organism is heterozygous at some gene loci, its gametes will not be identical (because of crossing over and random assortment of the maternal and paternal chromosomes). However, repeated self-fertilization will lead to homozygosity and then the gametes will be identical because both the maternal and paternal chromosomes will contain the same hereditary information.
7. $2^8 = 256$.
8. Dispersal of the species and dormancy during periods unsuitable for growth.

Chapter 17. Genetics: The Work of Mendel

The material of this chapter is developed to provide a brief case study of the interaction of facts and theories in the development of science, and the teacher may wish to emphasize this aspect.

A dihybrid *Drosophila* stock can be prepared by the students (e.g. red eye–curved wing X sepia eye–straight wing or dumpy wings–normal body X normal wings–ebony body) and then crossed to secure an F_2 generation. This work can be interspersed with other laboratory work over a span of four weeks. The procedures are included in Exercise 21 of the laboratory manual and illustrated in the film loop *Experimenting with Drosophila* (Ealing #81-0762). Data on continuous variation (such as that shown in Fig. 17.9) can be collected for use both with this chapter and Chapter 32.

Answers to Exercises and Problems

1. Somaplasm = body cells; germplasm = reproductory cells.
2. No. Bacteria consist of just a single cell which carries out all the functions of the organism, both vegetative and reproductory. Plants have both body cells and repro ductory cells, but the former can easily give rise to the latter. The reproductory cell are not set aside early in embryonic development.
3. JKL, JkL, JKl, Jkl,
   jKL, jkL, jKl, jkl.
4. No. Whether a *particular* sperm nucleus or egg contains R or r is entirely a matter o chance. Many pollen grains are formed but not used. Many alleles will have been segregated into the polar bodies during the development of the female gametophyte. Therefore, although approximately *one-quarter* of all the seeds produced will be RR one cannot be sure that 2 out of a given sample of 8 seeds will be so.
5. Tt.

	T	t
t	Tt	tt
t	Tt	tt

Backcross or Testcross.

6. The plants are hardy, normally self-pollinated, and exist in many varieties with pure-breeding, distinctive traits.
7. A fact is something which can be observed. A hypothesis is an explanation of why t facts are as they are. However, as methods of observation become increasingly indirect, the distinction becomes blurred. Is it a fact that the unit membrane is composed of protein and lipid layers or is it an explanation of the things observed in permeability and electron microscope studies? Perhaps our interpretation of what is seen under the electron microscope is incorrect and simply represents an artifact pro duced by the rather drastic methods of specimen preparation.
8. Only red-straight. In the F_2, there will be

   red-straight: red-curved: sepia-straight: sepia-curved = 9:3:3:1.

	RS	Rs	rS	rs
RS	$RRSS$	$RRSs$	$RrSS$	$RrSs$
Rs	$RRSs$	$RRss$	$RrSs$	$Rrss$
rS	$RrSS$	$RrSs$	$rrSS$	$rrSs$
rs	$RrSs$	$Rrss$	$rrSs$	$rrss$

9. Nine.
10. Multiple-factor inheritance with two gene loci participating. Pure-breeding tall ($TTT'T'$) mated with pure-breeding short ($ttt't'$) produces a uniform population of intermediate height ($TtT't'$). Mating two of these would produce plants in 5 different height categories with 1/16 of them short.

	TT'	Tt'	tT'	tt'
TT'	$TTT'T'$	$TTT't'$	$TtT'T'$	$TtT't'$
Tt'	$TTT't'$	$TTt't'$	$TtT't'$	$Ttt't'$
tT'	$TtT'T'$	$TtT't'$	$ttT'T'$	$ttT't'$
tt'	$TtT't'$	$Ttt't'$	$ttT't'$	$ttt't'$

11. The increased number of categories coupled with the varied effects of the environment make a sharp distinction between each category difficult and thus numerical analysis is difficult.
12. One of two entities, in diploid organisms, that control the expression of a trait and that are inherited from the parents of the organism, one from each.

Chapter 18. The Chromosome Theory of Heredity

In answer to the question on p. 362, assuming that the white-eyed parent was homozygous (a false assumption, as it turns out), it would have contributed one allele to each of the offspring. In answer to the question on p. 370, the reason that the answer is 7.2% is that only *half* the gametes produced by gamete-forming cells that had crossed over between the *C* and *S* loci will show the crossover. The other half will contain the chromatid that did not cross over in the tetrad.

The film *Medical Genetics–Part I* (Dept. of Professional Education, National Foundation, 800 Second Ave., New York 17, N.Y.) examines the chromosomal basis of inheritance with emphasis on the human. This film includes a consideration of some of the chromosomal abnormalities found in humans.

In the laboratory, the student can prepare stained, squash mounts of the giant chromosomes of *Drosophila* salivary glands. These can be secured from the larvae produced by the mating carried out as part of the laboratory work described for Chapter 17. Instructions are given in Exercise 21 of the laboratory manual. Prepared microscope slides are available to demonstrate drumsticks and Barr bodies in human cells (Carolina Biological Supply Co., Burlington, North Carolina); also colchicine-induced polyploidy and radiation-induced chromosomal aberrations (General Biological Supply House, Inc., Chicago, Illinois) are available.

Answers to Exercises and Problems

1. No. With 7 pairs of homologous chromosomes, at least two of 8 traits studied woul have to show linkage as the genes controlling them would have to be on the same chromosome.

2. All their sons would be color blind and all their daughters would have normal vision (although they would be "carriers" of the trait).

	X^C	Y
X^c	X^CX^c	X^cY
X^c	X^CX^c	X^cY

3. 22.

4. Both are present in pairs, one of each pair having been inherited from each parent. both cases, the members of a pair are separated during meiosis. Furthermore, chron somes are randomly assorted during meiosis as many (nonlinked) genes are.

5. Female. Male. (Autosomes carry the genes for maleness in fruitflies while in mammals the Y-chromosome does.)

6. Complete linkage between the genes for height and the genes for color; in fact, prob ably both traits are the expression of a *single* pair of genes.

7. The smallest part of a chromosome that can be separated at crossingover.

8. Recessive lethal genes present on the X-chromosome will always be expressed in ma but unless present in the double dose, not in females.

9. 

10. ♂, ♀, ♀, ♂, ♀, ♂, ♂.

11. 1, 2, 0, 0, 3, 2, 3.

Chapter 19. The Nature and Action of Genes

In answer to the question at the bottom of p. 389, crossing over of these loci at the first meiotic division could produce the following combinations (all of which are regularly observed): *AAaaAAaa, AAaaaaAA,* or *aaAAAAaa*. In answer to the question on p. 391, the 50:50 ratio in the ascus would not have occurred if more than one gene locus were involved. If, for example, two gene loci were involved, a phenotype ratio of 3:1 would be produced, three-quarters of the spores having one phenotype, one-quarter the other (depe ing on whether the recombinants did or did not produce the enzyme).

In Exercise 22 of the laboratory manual, the one gene-one enzyme relationship is studied with the bacterium *E. coli mutabilis*. Included in this exercise are directions for

carrying out several basic bacteriological techniques such as the Gram stain, preparing a streak plate, the use of fermentation tubes, and determining the spectrum of antibiotic sensitivity.

The use of *Neurospora* to demonstrate the one gene-one enzyme relationship is explained in *Neurospora Techniques*, two film loops that show how *Neurospora* is cultured, how an albino strain is crossed with the wild type, and how the ascospores are removed and tested. These loops are no longer available from Ealing, but may be purchased from Thorne Films, 1229 University Avenue, Boulder, Colorado, 80302 (catalog numbers 30-1 and 30-2).

Examination of water uptake, starch-grain structure, and phosphorylase activity in wrinkled and smooth peas gives some appreciation of the multiple effects of a single gene. Growing, in light and in dark, seeds of the F_2 generation of sorghum that is hybrid for albinism demonstrates the interaction of heredity and environment. (Seeds are available from General, Biological Supply House, Inc., Chicago, Illinois.)

Answers to Exercises and Problems

1. Multiple factors are two or more *pairs* of genes (each pair at a different gene locus) which control the same trait. Multiple alleles are three or more alleles, all associated with a single gene locus, that control a given trait. A diploid organism can have no more than two of these alleles although many others may be present in the population.
2. $2^7 = 128$.
3. ATP, NAD, cytokinins, Coenzyme A, FAD (flavin adenine dinucleotide).
4. Yes. The cells produced by the meiosis of a heterozygous nucleus (followed by a single mitosis) are held within the ascus. The two alleles will have segregated at either the first or second meiotic division.
5. In the case of *Neurospora*, the products of the meiotic division of a single nucleus are kept together and not mixed with the products of other meiotic divisions (as occurs in the production of pollen) or sequestered in polar cells (as occurs in the production of eggs).
6. CGA, CUA, GGU, UUU, UCA.
7. Each gene is expressed, even though recessive, because only one gene is present for each gene locus. In diploid organisms, the presence of a recessive gene may be totally masked by the simultaneous presence of a dominant allele.
8. They cannot manufacture food by photosynthesis and thus die when the food stored in the seed is exhausted.
9. *Aa*.

	A	a	
A	AA	Aa	
a	Aa	aa	— albino

10. Because albino plants do not live to maturity, they cannot be used as one parent in the production of heterozygous offspring. Therefore, the plant breeder must cross green plants and then test some of the seeds produced by germinating them. If no albino seedlings develop, either both parents were AA or one was AA and the other Aa. However, those plants that do produce a few aa seeds must have been Aa. The *remainder* of this crop of seeds can now be sold secure in the knowledge that they a F_2 offspring.

11. Because of the statistical nature of genetic analysis, large samples of offspring are d sirable. The shorter the generation time of one's test organism, the more rapidly breeding experiments can be carried out.

12. Luminous dials emit high-energy radiation which might measurably increase the rat of mutation in nearby cells. The low incidence of such mutations should be no cau for alarm unless an affected cell might function as a gamete, thus transmitting the mutation to every cell of the resulting offspring. Only cells in the gonads could ser such a function.

13. Yes. He recognized that only changes occurring in the gamete-producing cells, the germplasm, could be transmitted to the next generation.

14. Assuming that most of an organism's genes represent alleles that have a definite sur vival value (e.g. by producing an important enzyme), any change in a gene may wel prevent it from doing its job as effectively as before; that is, it may no longer produ an active enzyme. In a diploid, heterozygous organism, however, its unmutated all would continue to produce the enzyme, thus masking the presence of the mutant allele. Only when present in the double dose would its effect be evident.

15. NO_3^-, $SO_4^=$, K^+, $PO_4^=$, Na^+, Mg^{++}, Cl^-, Fe^{++}, Cu^+, Mn^{++}, Zn^{++}, Ca^{++}, B^{+++}, Mo^+.

    To provide the elements needed for the synthesis of proteins, nucleic acids, and ma coenzymes.

16. No. It simply means that *E. coli* (but not *Neurospora*) has the enzyme systems for synthesis of biotin from the glucose, NO_3^-, and $SO_4^=$ in its medium.

17. That portion of a DNA molecule that encodes the synthesis of a single polypeptide chain. No.

18. (a) The production of miniature plants from cells at the margins of the leaves requ the duplication of these cells by mitosis.
    (b) The duplication of green plant cells requires the prior duplication of the chrom somes. Each daughter cell also must receive at least one proplastid or chloropla These arise by the duplication of proplastids.
    (c) Duplication of the chromosomes requires the duplication of the DNA molecule of which they are composed. This is probably also true of chloroplasts; perhaps mitochondria.

19. They can give rise to large numbers of offspring whose genes are identical; that is, t can give rise to clones. Organisms that only reproduce sexually (e.g., *Drosophila*) usually produce offspring that differ from the parents and from each other because of the reshuffling of the genetic code during meiosis and fertilization.

0. If there is no cross-over, *AAAAaaaa*. If a cross-over has occurred between the locus and the centromere, *AAaaAAaa* or *AAaaaaAA*, or *aaAAAAaa*.
1. No.
2. Because of the frameshift, the nucleotides that had coded for Val (No. 18) and Thr (No. 19) would now produce a stop signal: · G $\boxed{U\ G \cdot A}$ C U ·
3. Ser – Ser – Pro – Gln – Pro – Glu – Phe – Glu – Ala – Tyr – Leu – Leu – Thr – Leu – Leu – Ser – Ser – Phe – Ser – Thr – Met – Ala – Glu – Leu – Ala – Thr.

hapter 20. Sexual Reproduction in Plants

In answer to the question on p. 419, a pollen grain germinating on the cone of another lant has accomplished cross-pollination and thus promoted greater variability than occurs ith self-pollination. On p. 429, an enforced period of dormancy has survival value in pre- nting germination during unseasonably mild weather late in the fall. Germination with the ssurance of light for the developing seedling (also on p. 429) is of value in marshy locations ecause a sunny location will also provide adequate moisture. In the desert, on the other and, a seed germinating in the presence of light may soon be dried out and the seedling illed.

Several films are available that show dispersal and germination of seeds, using time- pse photography where appropriate. Two of these are: *Seed Dispersal* (United World) nd *Seed Germination* (Encyclopaedia Britannica Films, Inc.). The film loop *Gamete Trans- r in the Bryophytes–The Splash Cup in a Moss* (Ealing #81-5209) shows the transfer of otile sperm from antheridia to archegonium in a moss. The film loops *Pollen Tube Growth* aling #81-5696) and *Growth and Pollination of Corn* (Ealing #81-9698) are also appro- iate to use with this chapter.

The dissection and study of moss and fern reproductory organs and of representative owers, seeds, and fruits can be undertaken in the laboratory. Instructions are given in xercise 24 of the laboratory manual (which also includes directions for germinating pollen ains).

nswers to Exercises and Problems

1. (a) At tip of stalk of sporophyte, (b) On leaflets, (c) In cones, (d) On stamens and in pistil of flower.
2. Each is haploid, starts with a spore, and produces gametes.

3. The moss gametophyte is the dominant stage in the life cycle, with the sporophyte dependent upon it for water and, perhaps, for some of its food. The fern gametoph is much smaller than the sporophyte although the sporophyte, for a brief time, is dependent upon it. The angiosperm gametophyte is microscopic in size and entirely dependent upon the parent sporophyte for nourishment. Except for the pollen grai it can be seen only by dissecting the tissues of the flower.
4. Each is diploid, starts with a zygote, and produces spores.
5. They have rhizoids for anchorage and absorption of water, can withstand prolonged drought in a dormant condition, and are dispersed by drought-resistant wind-blown spores. They have no supporting tissues, and no true roots nor vascular system for efficient absorption and transport of water and are therefore limited to a small size. They require free water in order for sexual reproduction to take place.
6. Moisture, oxygen, and a suitable temperature.
7. A period of dormancy; exposure to light or dark.
8. Take a large sample (at least 100) and plant them under optimum conditions (whic could, if necessary, be determined first by planting newly-harvested bean seeds und varying conditions of temperature, moisture, and depth of planting). Determine th percent that germinate. In order to have a basis for comparison, a control should b run at the same time under identical conditions with a sample of freshly-harvested beans of the same variety.
9. Take freshly-harvested beans and plant at least 100 in each of several containers, ke ing all factors (e.g. depth of planting, watering of soil) the same. Then place each container in a different (and constant) temperature. Determine the percent of bea that germinate at each temperature.
10. Endosperm.
11. (a) Spore mother cells, (b) Megaspore and microspore mother cells.
12. No. The genetic similarity of gametes produced by the same parent would reduce t amount of variability in the offspring. Even if the violet were heterozygous at man gene loci at first, continued self-fertilization would increase the degree of homozygosity and therefore decrease the amount of variability. With drastic changes in the environment, the violet might be unable to produce variants able to cope with the changed conditions and extinction would follow.
13. Seeds. Fruit.
14. (a) Anthers and ovules in a flower ripen at different times.
    (b) Stamens and pistil placed or shaped so that pollen from stamens of one flower i unlikely to reach the pistil of the same flower.
    (c) Self-sterility. Pollen will not germinate on the pistil of the same flower.
    (d) Dioecy.

Chapter 21. Sexual Reproduction in Animals

A dissection of the reproductory organs of male and female frogs is appropriate laboratory work for this chapter. A suspension of living frog sperm can be prepared and examined microscopically. Ovulation can be induced by prior treatment of a female frog with pituitary extract. The eggs can be fertilized after stripping them from the uteri. Instructions for these procedures are given in Exercise 26 of the laboratory manual.

The excellent film loop *Fertilization and Cleavage* (Ealing #81-5993) shows each step in the process of the fertilization of a sand dollar egg, and includes views of the early stages of cleavage.

Exercise 25 in the laboratory manual gives instructions for the dissection of an anesthetized earthworm, with emphasis on the reproductory organs and the development of sperm cells.

Answers to Exercises and Problems

1. Carrying fertilized eggs within their body would overload birds and make flying more difficult.
2. Sperm are cells, the male gametes. Semen is a mixture of sperm cells and the fluids in which they are suspended.
3. They are similar in that in each case a diploid cell undergoes meiosis with three of the four haploid cells produced having little cytoplasm and eventually disintegrating. They are different in that in the frog, the single cell remaining is the egg and is fertilized directly, while in the bean, it is the megaspore and undergoes 3 mitotic divisions of its nucleus before fertilization of one of the 8 resulting cells takes place.
4. In amplexus, the male grasps the female and deposits sperm over the eggs as she lays them. In copulation, the male deposits his sperm *within* the female's body.
5. (a) Water, (b) Genital tract, (c) Genital tract, (d) Water, (e) Fallopian tube.
6. 50:50. Chance has no memory.
7. 4 ($2^2 = 4$). Also 4.
8. Animals generally have the power of locomotion and thus can seek out a mate. Plants do not and may have to rely on self-fertilization if cross-pollination does not occur.
9. Generally, no. The number of sperm produced is related to the circumstances in which fertilization takes place; that is, the likelihood of sperm reaching a majority of the eggs produced. In nearly every case, this requires many more sperm cells than eggs. Sperm cells unsuccessful at fertilization simply die with no great loss of matter and energy to the organism producing them. The same would not be true of the food-filled eggs which are usually produced in numbers just great enough to assure that each generation replaces itself.

10. (a) Form the spindle to which the chromosomes are attached during meiosis.
    (b) One organizes the tail of the sperm cell.
    (c) After union of sperm and egg, this centriole then participates in the formation of the spindle which will bring the paternal and maternal chromosomes together in the zygote nucleus.

Chapter 22. Development: Cleavage, Morphogenesis, and Differentiation

The eggs fertilized as part of the lab work for Chapter 22 can be observed through their developmental stages up to the hatching of the larva, although the students will miss seeing some of the stages unless the eggs are fertilized in staggered batches. Preserved who mounts and sections of frog embryonic stages can be secured from biological supply house

One of the outstanding films in biology is *Amphibian Embryo* (Encyclopaedia Britannica Films, Inc.). In this film, which shows the development of both salamander and fr eggs, time-lapse photography is used to reveal the dynamics of the process in a way that n verbal description could possibly equal. Labels and diagrams are also used to enhance the film's effectiveness as a teaching device.

Ealing film loops *Frog Egg*—Parts 1, 2, and 3 (#81-4368, #81-4376, and #81-438 cover much of the same material but lack the explanatory diagrams.

Answers to Exercises and Problems

1. Ectoderm.
2. Identical twins arise from a single zygote. They are always of the same sex. Fraterna twins are simply two offspring that started development at the same time, each fron its own fertilized egg.
3. Examination of embryonic development reveals that the liver develops as an outgrowth of the archenteron which itself develops from endodern (see Fig. 29–1).
4. The uptake of water by the embryo.
5. Each of the 4 cells produced by two mitotic divisions of the armadillo zygote devel into a complete embryo. Thus 4 identical quads result.

6. Mutations in regulator genes are inherited as recessives because in the heterozygotes there is still a functional gene producing the repressor protein.
7. Mutations in operator genes are inherited as dominants because in heterozygotes the mutant gene fails to respond to the repressor and therefore turns "on" *its* adjacent structural genes even though the other operon is repressed.

Chapter 23. Development: Growth, Repair, Aging, and Death

In answer to the question on p. 483, one difference between regeneration and embryonic development is that in the former there are already-differentiated tissues nearby that could set up inductive or inhibitory influences. On p. 490, the greater life span of human females is not necessarily hereditary. The differences in the activities carried out by women and men throughout their lives might possibly have a differential effect on their life span.

In the laboratory, the growth of the primary leaves of bean plants started every other day for the preceding three weeks can be measured and a growth curve plotted. See Exercise 27 in the laboratory manual for directions. Regeneration in planarians also makes interesting study.

In the film loop *Early Development of the Shoot in Quercus* (Ealing #81-5571), time-lapse photography of a germinating acorn shows development of the apical meristem and the leaf primordia.

Answers to Exercises and Problems

1. The beef protein is first hydrolyzed into a mixture of amino acids by the proteases of the stomach, pancreas, and intestine. The amino acids then are absorbed into the blood and transported to the cells where protein synthesis is taking place. The amino acids are activated by ATP and each unites with a specific molecule of transfer RNA. The transfer RNA molecules then unite with complementary triplets on a molecule of messenger RNA. The order of triplets determines the order in which the transfer RNA molecules join with the messenger RNA and thus the order of amino acids in the growing polypeptide chain. Because the sequence of triplets in the messenger RNA molecule is a copy of the triplet sequence in part of a DNA molecule, the polypeptide that is produced contains a sequence of amino acids dictated by the particular hereditary code of the cell which is, in turn, the code of the entire organism.

    1 2 3 4 5
2. 5 ($2 \times 2 \times 2 \times 2 \times 2 \times 2 = 64$ trillion).
3. Geometric progression. The product of growth generally grows itself. For some organs in some organisms, this may not be strictly so. For example, where a great deal of extracellular matrix is formed in an organ, the growth of the organ may not be logarithmic.
4. An exponential decay curve (as in curve "*C*" of Fig. 30-5) with a half-life of 693 days ($N = 1000e^{-t/1000}$).

5. (a) No: little mortality until aging begins.
   (b) Yes: severe random mortality would mask effect of aging.
   (c) No: little mortality until aging begins.
   (d) Yes: severe random mortality would mask effect of aging.
   (e) Yes: no aging but random mortality throughout the life of any generation.
6. Microscopic algae. Insects, crustaceans, etc. The size of the tadpole's food is appropriate to the size of a tadpole while the size of the adult's food is not. The growth which the tadpole's diet makes possible enables the animal to reach a size appropria —after metamorphosis—to a diet of insects and other invertebrates.
7. In general, heredity, diet and exercise. Specifically, the production of HGH, protein intake, Ca^{++} intake, vitamin D production or intake, thyroid activity, perhaps production of sex hormones.
8. The liver, skin, intestinal epithelium, and bone marrow. The same.
9. The same. Organs which regenerate damaged protions easily are those capable of th rapid production by mitosis of new, and thus youthful, cells.
10. They are similar in that organs with fully differentiated cells are produced from mas of unspecialized, embryonic cells. They are different in that regeneration occurs in the proximity of already-differentiated cells whereas embryonic development gener does not.

PART V. RESPONSIVENESS AND COORDINATION

Chapter 24. Responsiveness and Coordination in Plants

In answer to the question on page 512, ATP and NAD (as well as coenzyme A and flavin adenine dinucleotide) contain adenine.

A variety of demonstrations [coleus on side; coleus illuminated by unidirectional light, IAA in lanolin on coleus petiole (Fig. 24.15), response of *Mimosa* leaflets, etc.] can be carried out for this chapter. The germination of Grand Rapids lettuce seeds exposed to red and far-red light makes a dramatic demonstration. In the laboratory, the effect of varying concentrations of IAA on the elongation of coleoptile sections and roots of the oat can be measured. Instructions and data sheets are provided in Exercise 14 of the laboratory manual.

Four film loops on the phytochrome story are:

a) *Effects of Red and Far-Red Light on Seedling Development* (Ealing #81-5522)
b) *Isolation of Phytochrome* (Ealing #81-5530)
c) *Photochemical Properties of Phytochrome* (Ealing #81-5548)
d) *Effect of Red and Far-Red Light on Internode Length* (Ealing #81-5555)

Answers to Exercises and Problems

1. Geotropisms will ensure that the root grows down and the stem grows up.
2. Geotropism and phototropism of roots and stems, fruit development, apical dominance, some cases of bud dormancy, abscission of leaves and fruits, initiation of adventitious roots, selective weed killing.
3. Thermonasty.
4. An experiment set up in duplicate with all factors, except the one whose influence is being examined, kept the same and, ideally, optimum.
5. No. He should have left some flowers untreated to be sure that something else (e.g. pollination) was not actually causing the development of fruits.
6. The unchilled buds.
7. A plant with its terminal shoot replaced by a block of plain agar should have been included to eliminate the possibility that agar alone maintains apical dominance.

8. (a) i. In the terminal bud by the absorption of light by a pigment, probably a carotenoid.
    ii. In the region of cell elongation by the more rapid elongation of the cells on t shady side.
    iii. By the translocation of auxin from the terminal bud to the shady side of the stem.
   (b) i. In the leaf by the absorption of light by phytochrome.
    ii. In the apical meristem by its conversion into a flower bud.
    iii. By florigen translocated in the phloem.
   (c) i. By cells in the embryonic region. How the stimulus is detected is not yet known.
    ii. In the region of elongation by the more rapid elongation of the cells on the upper side.
    iii. By the translocation of auxin from the embryonic region to the region of elongation. The higher concentration of auxin on the under side inhibits cell elongation while the lower concentration on the upper side stimulates cell el gation. (The experimental evidence for each is described in the chapter.)

Chapter 25. Chemical Coordination in Animals

In answer to the question on p. 536, insulin must be given by injection rather than b mouth because the proteases of the human digestive tract would destroy it. When it is des to force female frogs to ovulate (p. 539), they are injected with pituitary extract because the FSH and LH present.

The effect of various drugs (including tranquilizers) on frog chromatophores is an appropriate and relatively simple demonstration that can be carried out at this point.

Answers to Exercises and Problems

1. The secretion of insulin lowers the blood sugar level. The secretion of glucagon, glucocorticoids, ACTH (indirectly), and adrenaline *raise* the blood sugar level.
2. Glucocorticoids tend to depress the hormone output of the anterior lobe of the pituitary, of ACTH especially but also of HGH.
3. Insulin is a protein and would be digested by the proteases of the stomach and intestine.
4. (a) Small amount of a very concentrated urine.
   (b) Large amount of a watery urine containing glucose.
   (c) Large amount of watery urine.
5. The adrenal cortex, thyroid, interstitial cells of the testes, and the follicle and corpu luteum of the ovary. The anterior lobe of the pituitary must also be included as *its* output is influenced by the hormones of the other glands listed.

6. The various organs in an organism each carry out one or more specific functions upon which all the others depend. The individuals in a society may also be specialized or assigned to carry out certain specific functions upon which the others depend. In both cases, a system of communication between these functional units enables their functions to be carried out at the correct time and to the correct degree.
7. By hormones and nerves.
8. By visual, sound, touch, and chemical (pheromones) signals.
9. It enables the insect to remain dormant and survive unfavorable conditions, e.g. winter.
10. (a) As the concentration of water in the blood decreases, the posterior lobe of the pituitary is stimulated to release vasopressin which acts upon the distal tubules increasing the reabsorption of water into the bloodstream. As the concentration of water in the blood increases, the posterior lobe of the pituitary is inhibited and reabsorption of water from the distal tubules decreases.
    (b) As the temperature of your home decreases, the thermostat controlling your furnace is activated and turns on the furnace. As the temperature then rises, the thermostat is deactivated thus shutting off the furnace.

Chapter 26. Nervous Coordination: Stimulus Receptors

In answer to the question on p. 578, another possible explanation of the results secured in the test shown in Fig. 26.17 is that substances are produced by the electrolysis of saliva which are then tasted. Perhaps this possibility could be tested with a dry tongue.

In the laboratory, the mapping of touch, heat, and cold receptors in the skin can be carried out. The taste areas of the tongue can be mapped using solutions of NaCl, vinegar, sucrose, and quinine sulfate. Instructions are given in Exercise 15 of the laboratory manual.

The film loop *Cecropia Moth Life History* (Ealing #81-3279) shows the feeding and molting of the larva, the spinning of the cocoon, the emergence of the adult, egg laying, and the hatching of the eggs.

Answers to Exercises and Problems

1. Looking to one side allows the light rays to fall on the rods instead of on the cones of the fovea (which are much less sensitive).
2. Eyes; the temperature, touch, pressure, and pain receptors in the skin; the proprioceptors of the muscles (indirectly); the organs of Corti; the semicircular canals; the sacculus and utriculus (static balance); and the olfactory epithelia detect events occurring outside of the body. The temperature receptors of the hypothalamus, the pressure and pain receptors within the body, the lactic acid detectors in the carotid arteries, the carbon dioxide detectors in the carotid arteries and medulla oblongata, the pressure receptors in the aorta and carotid arteries, the stretch receptors in the right auricle, the osmotic pressure detector in the hypothalamus, and (in a sense) the taste buds detect events occurring within the body.

3. Vitamin A is a precursor of rhodopsin which is the pigment found in the rods, the light receptors used at night.
4. Odors do not reach the olfactory epithelium and odors play a large role in what we ordinarily consider to be taste.
5. Cell membrane, nuclear membrane, endoplasmic reticulum, Golgi complex, vacuolar membranes, mitochondria, lysosomes, lamellae of chloroplasts, and rhodopsin-conta ing lamellae of the rods of the retina.
6. A change in the environment which can be detected.
7. Our touch and pressure receptors become adapted; that is, they cease to initiate impulses upon prolonged mechanical deformation. In other words, when the force cea to represent a *change* in the environment it ceases to be a stimulus.
8. Probably the creation of a generator current in the neuron to which they are connected.
9. They both form an image of objects in front of them. They both have individual lig receptors which detect light reaching them from a given spot in the area being viewe They are different in that the compound eye has a lens in front of each cluster of 6 to 8 receptor cells pointed at a given spot in the visual field, while the human eye ha just a single lens which gathers light from all parts of the visual field and forms an image on an area of the retina containing many individual light receptors.

Chapter 27. Nervous Coordination: The Conductors

The spinal reflex can be examined in an intact, single-pithed, and double-pithed frog The sites of fatigue can be demonstrated by stimulating – in order – the spinal cord, sciat nerve, and gastrocnemius muscle of a beheaded frog. With a nerve chamber, stimulator, an oscilloscope (available from a number of manufacturers), the nerve impulse in a frog sciati nerve can be displayed easily and the effects of stimulus voltage and duration can be studi Exercise 17 of the laboratory manual also describes these procedures. It includes directior for measuring the velocity of conduction of three classes of fibers in the sciatic nerve and for demonstrating the effects of CO_2, ether, proximal-distal reversal of the electrodes, and mechanical damage on the propagation of the nerve impulse.

The procedure for excising the nerve-muscle preparation used in this exercise is described in the laboratory manual. It is also shown in the author's film loop *Nerve Impul* Part I (Ealing #81-5605). *Nerve Impulse*–Part 2 (Ealing #81-5647) shows how the nerve-muscle preparation is connected to the recording equipment and the appearance of the ne impulse on the screen of the oscilloscope.

Answers to Exercises and Problems

1. The meninges.
2. Eyes, semicircular canals, sacculus and utriculus, proprioceptors, spinal cord, cerebr

and cerebellum.

3. Impulse generated in receptors of limb → sensory axons → dorsal root → association neurons in gray matter of spinal cord → motor neuron axon → ventral root → skeletal muscle.
4. (a) Closes it down, (b) Stimulates secretion.
5. It enables them to shine light into the interior of the eye without reflex closing down of the pupil.
6. The right side.
7. Cranial nerves run from the brain to receptors and effectors in the head. While some of them are mixed nerves, some (e.g. the optic nerves) consist solely of sensory axons and some (e.g. oculomotor) consist mostly of motor axons. Spinal nerves run from the spinal cord to receptors and effectors of the body. All of them are mixed nerves.
8. Increase in rate and strength of heartbeat: more rapid flow of blood to supply needs of violent activity.
   Blood shifted from skin and viscera to skeletal muscles, coronary arteries, and lungs: permits increased activity of the skeletal muscles by supplying increased amounts of glucose and O_2, and removing wastes more rapidly.
   Spleen contracts: increased volume of blood and hemoglobin.
   Rise in blood sugar: fuel for violent activity.
   Bronchi dilate: increased gas exchange.
   Pupils dilate: the better to see the danger.
   Clotting time of blood reduced: provides for speedy clotting in case of damage to blood vessels.
   Increased blood pressure: increased formation of lymph.
   Stimulation of sweat glands: removes heat produced by violent muscular activity.
   Inhibition of peristalsis: contents of alimentary canal do not move forward during period when blood supply to viscera and intestinal secretion are reduced.
9. A nerve is a bundle of axons (both sensory and motor in the case of mixed nerves). A neuron is a single nerve cell consisting (usually) of dendrites and cell body as well as an axon.
0. Clusters of cell bodies and the location of synapses.

apter 28. Nervous Coordination: The Effectors

Cyclosis in *Anacharis (Elodea)*, streaming in *Amoeba*, ciliary action in *Paramecium,* d bioluminescence are appropriate demonstrations or laboratory exercises for this chapter.

The action of adrenaline and acetycholine on cardiac and smooth muscle in a frog are nveniently studied in the laboratory. Exercise 16 of the laboratory manual provides de- led instructions. The effect of these substances on the frog heart is also demonstrated in e author's film loop *Frog Heart Muscle Response* (Ealing #81-5621). The graded response skeletal muscle to shocks of increasing voltage can be studied using the frog gastrocnemius d the apparatus illustrated in Fig. 28.6. Tetanus and fatigue can be demonstrated with

the same preparation. Full instructions and data sheets for these procedures are include Exercise 16 of the laboratory manual. These phenomena can also be viewed in the auth film loop *Frog Skeletal Muscle Response* (Ealing #81-5613).

Answers to Exercises and Problems

1. ATP → ADP; then CP → C + ~ Ⓟ; then $C_6H_{12}O_6 \rightarrow 2C_3H_6O_3$ + ~ Ⓟ. Through and after the race is over,

$$C_6H_{12}O_6 + 6O_2 + 6H_2O \rightarrow 6CO_2 + 12H_2O + \sim Ⓟ.$$

(Some lactic acid is also respired during recovery.) During recovery, ~ Ⓟ is used t resynthesize glycogen (from lactic acid), CP, and ATP.

2. Its most dramatic symptom is sustained maximal contraction of such skeletal musc as those of the jaw.
3. Smooth.
4. Motion and locomotion: femur, tibia, etc.
   Protection of vital organs: cranium, vertebrae, ribs, sternum.
   Production of blood corpuscles: sternum, ribs.
   Support of the body: limb bones, pelvis, vertebrae, and most other bones.
5. The fiber.
6. The motor unit.
7. Pyruvic acid is not decarboxylated and thus the end product of its reduction is lact acid, not ethanol and CO_2.
8. They are similar in that both have a resting potential across the cell membrane whi may be reduced to a threshold value by some neurohumor (such as ACh) initiating in an all-or-none way, an action current. This is followed by a refractory period in both instances. They differ in that the action current is followed by contraction ir case of the muscle fiber and the energy for the cell's activity can come from fermer tion. In the neuron, the impulse is followed by the release of a neurohumor and th energy for the active transport of Na^+ and K^+ ions comes from cellular respiration only.
9. The small size and hence large surface area: volume ratio of hummingbirds makes a most continual muscular activity and feeding necessary for the maintenance of hor thermy. With the lower temperatures of night and the darkness which interferes w feeding, the birds roost and their body temperature drops. The birds become torpi during this period.
10. Nerve impulses, muscular contraction, active transport, cytoplasmic streaming, bea of cilia and flagella, biochemical syntheses, production of heat, emission of light.
11. (a) Skeletal muscle: straight, striated, multinucleate fibers attached to the skeleton with a relaxation period longer than their refractory period permitting tetanus occur. Can sustain a substantial oxygen debt.

(b) Cardiac muscle: branched, striated, multinucleate fibers that make up the wall of the heart. Refractory period longer than relaxation period so tetanus does not occur. Can sustain little or no oxygen debt.

(c) Smooth muscle: single, spindle-shaped cells (one nucleus) with no striations visible. Slow contraction. Can maintain tonus without continual input of energy. Lines all the hollow organs of the body.

2. Tetanus is *sustained* maximal contraction (of a motor unit or an entire muscle) while tonus is sustained partial contraction of an entire muscle. Tonus in skeletal muscles is maintained by the synchronous phasing in and out of tetanus of a certain number of motor units.

3. The degree of contraction of an entire muscle is a function of the *number* of motor units which contract (the fibers of each motor unit contracting in an all-or-none fashion).

4. In both cases there is a resting potential across the membrane which is reduced to the threshold value by the liberation of acetylcholine at the end plates of the motor axons that terminate on them. Each one has a refractory period before repolarization is complete.

hapter 29. Behavior

Several films are available to demonstrate various aspects of animal behavior. Some these are: *Story of the Bees* (United World), *The Honeybee–A Social Insect* (Encyclo-edia Britannica Films, Inc.), *Biography of a Fish* (Stickleback) (Sterling Educational Films, c.), *Motivation and Reward in Learning* (Yale University).

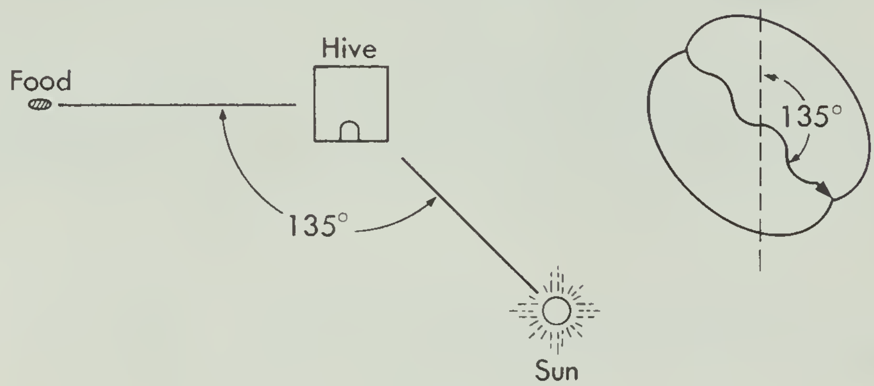
In addition, film loops are available (BFA Educational Media, 2211 Michigan Ave., nta Monica, California 90404) on such topics as courtship, escape, territorial, and predatory havior, and on cleaning symbiosis. Outstanding among these are *Courtship Behavior in the ickleback* (Ealing #81-5977) and *Behavioral Experiments with the Stickleback* (Ealing 1-5985).

Reflex behavior, conditioning, trial and error learning, learning with and without ing able to make associations and with and without distractions, and other aspects of man behavior can be studied in the laboratory. Instructions are given in Exercise 19 of e laboratory manual. Responses in *Paramecium* can be studied using the apparatus scribed in Exercise 3 of the laboratory manual. A dissection of the legs, mouth parts, ng, and wings of a worker bee will reinforce the material on bee behavior. These proce-res are described in Exercise 18 of the laboratory manual.

swers to Exercises and Problems

. Feed sugar water on a scented card 200 yards from the hive. After scouts have fed and returned to the hive, place scented cards only at various compass bearings equidistant from the hive. If a substantially greater number of *new* foragers arrive at the cards in the same general direction as the original food supply, one may conclude that directional signals had been transmitted from the scouts to the other foragers.

2. Train bees to feed at a scented card. Remove their antennae. Place several cards, each with a different scent (one of which is the original) at that location and see if the antennae-less bees find their way to the card with the original scent. If they do not, the experiment should be repeated with bees trained to color in order to be su that the shock to the bees of the operation is not preventing the bees from rememb ing *any* prior training.
3. If a buzzer is sounded each time the shock is applied, the subject eventually will wi draw his foot simply upon hearing the buzzer. During this procedure, the cerebral cortex is, in some way, circuiting impulses reaching it from the auditory nerves int motor tracts leading to the same motor neurons used when the unconditioned response was carried out.
4. West.



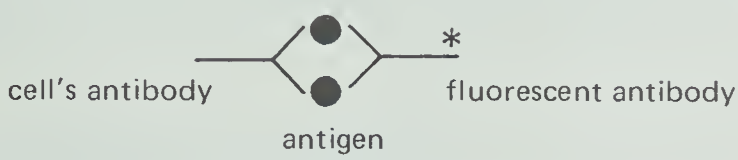
5. The straight portion of the dance will be oriented down. Approximately $4\frac{1}{2}$ turns the dance will be made during each 15 seconds.
6. The straight portion of the dance will be oriented 135° to the left of the vertical. Approximately 2 turns will be made during each 15 seconds.
7. Signalling by means of sounds, visual signals, chemicals that are smelled or tasted (pheromones), and touch.
8. Both tropisms and taxes are responses in a particular direction, the direction being determined by the direction from which the stimulus strikes the organism. Howev a taxis involves locomotion while a tropism involves a bending or growth movemen
9. By combining a slight shock to the foot with the sounding of one note on the pian one can condition the dog to withdraw his foot upon the sound signal alone. Sour the next higher whole tone, without applying the shock. See if by alternating the note *with reinforcement* (shock) and the higher note *without reinforcement* the re sponse to the first note is maintained while the response to the higher note is *extin guished*. If so, the discrimination is proven.
10. Feed the ants at a spot whose location is changed periodically but which is always illuminated by a particular color. After a period of this, remove the food and disp several colored spots taking care that the intensity of illumination is such that the amount of light reflected from each is nearly equal and thus would produce grays approximately equal density on wide-response black-and-white film. See that the color is not in the same location as before. If the ants come to it in preference to other colors, color vision can be inferred.

Chapter 30. The Immune Response

ABO blood group typing can be carried out in the laboratory and provides a nice example of an antigen-antibody reaction. Directions are included in Exercise 23 of the laboratory manual.

Answers to Exercises and Problems

1. The cells contain antipneumococcal antibodies and the fluorescent dye is attached to the same kind of antibodies. The antigen is thus needed to form a bridge between the cell's antibodies and the fluorescent antibodies. This is called the "sandwich" technique.



2. Antibodies directed against determinants located on mouse antibody molecules would bind to mouse antibodies and interfere with the binding of antigen to them. The fact that antimouse antibodies interfere with the binding of mouse lymphocytes to the antigen-coated fibers and red cells indicates that the receptors on the lymphocytes are, at least partly, the same as antibody molecules.

PART VI. EVOLUTION

Chapter 31. Evolution: The Evidence
Chapter 32. Evolution: The Mechanism

A laboratory exercise similar to that shown in Fig. 31.7, using such specimens as mollusk shells or conifers, gives the student a chance to see the principles and problems of grouping organisms by number of shared homologies. Whatever specimens used, some should be closely related, some not. Exercise 2 in the laboratory manual provides instruc tions and a worksheet.

The material of these two chapters can be reinforced by having actual specimens o fossils, vertebrate bones, organisms showing protective resemblance, etc. available. The loops *Animal Camouflage–Insects* (Ealing #81-3360) and *Warning Coloration & Behavi Insects* (Ealing #81-3378) are appropriate here. The movie *Heredity and Adaptive Cha Natural Selection* (Encyclopaedia Britannica Films Inc.) shows how the survival value of the melanic gene in *B. betularia* is actually measured as well as other examples of evoluti ary forces at work.

In answer to the question on p. 726, $p + q$ must always equal one if there are only two alleles in the population at a given gene locus because the two of them together acc for 100% (1.00) of the gene pool.

In the laboratory, the students can study continuous variation by measuring and p ting the heights or weights of classmates (as in Fig. 17.9). Populations of bean seeds or etc. also can be used.

Answers to Exercises and Problems (Chapter 31)

1. They have been entombed in sediments now at the bottom of the sea or within th rocky crust of the earth, or have been destroyed by erosion of these rocks upon e posure to the forces of wind and water.
2. Ontogeny = the development of the individual
   recapitulates = repeats
   phylogeny = the history of the particular taxonomic group.
3. No. The development of the individual often repeats phases in the *development* o species thought to be ancestral to it, not the adult forms of these species. At one the human embryo resembles a fish embryo—never an adult fish.
4. The rabbit and man. At stage III, they still resemble each other closely while the other embryos have begun to develop rather distinctive characteristics.

5. Inject a preparation of proteins (e.g., plasma) from a cow into the bloodstream of a rabbit. Repeat at intervals. Then bleed the rabbit and extract the gamma globulin fraction of its plasma. The antibovine antibodies will be present in it.

6. Bermuda is a volcanic, oceanic island which has never been connected by a land bridge to the continent. Presumably, in the past, most of the islands of the West Indies have been connected to each other and to the mainland.

7. Old World monkeys. The reaction between Old World monkey (e.g., mandrill) antigens and antihuman antibodies is greater than that between New World monkey antigens and antihuman antibodies.

8. Mollusks with their shells and aquatic habitat have left an extensive fossil record. Their shells do not decay and are resistant to mechanical damage. The bones of reptiles also are resistant to destruction although fewer terrestrial animals are likely to become fossilized. The soft bodies of flatworms would seldom be preserved before decay had destroyed them.

nswers to Exercises and Problems (Chapter 32)

. (a) The physical barrier presented by the canyon has isolated what was once a single species into two subpopulations. Either natural selection or random genetic drift has caused the two populations to develop a few distinct, consistent differences.

(b) If the canyon should be obliterated, the two populations would once more be in a position to breed with each other. If they did so, the differences between the two populations would quickly disappear and a single interbreeding population would be reestablished. However, even though in a position to do so, the two populations might not interbreed. Perhaps their differences in appearance would fail to evoke mating behavior between the two groups. Possibly their genetic differences are so great that successful hybridization could not occur. In any case, if interbreeding did not occur, the differences between the two populations would be maintained and they would be considered separate species. The differences between the two species might quickly become even greater as a result of the intense competition between the two groups for similar requirements of food and shelter. Unless structural, physiological, or behavioral differences evolved in the two groups that led to a reduction in competition for the necessities of life, the species that was better adapted to the existing conditions would probably drive the other to extinction.

The breeding members of a honeybee population are the drones and the queen. Both live highly-protected lives, thanks to the efforts of the workers in feeding them, guarding the hive, maintaining a constant temperature in the hive, etc. In other words, selective forces are minimal in the lives of both queens and drones.

"Living fossils" (e.g. *Neopilina, Latimeria, Limulus*) are usually found in the sea suggesting that this habitat has changed least during the history of life on this earth. The stability of the marine environment has enabled certain species that evolved long ago to survive to the present time with little evolutionary change.

4. A bilaterally-symmetrical, actively-feeding vertebrate must have a certain shape (torpedo-like and streamlined) and a means of propulsion and maneuvering in orde to live successfully in the sea. Despite the differences in their ancestry, the same f of natural selection acting on porpoises as have acted on fishes have resulted in poi poises evolving certain fish-like characteristics (e.g. torpedo shape). This is converg evolution.

5. Natural selection.

6. Random assortment and crossing over of chromosomes in meiosis. Outbreeding.

7. Outbreeding.

8. Mutations.

9. 42%. $q^2 = 0.09$, $q = 0.3$. $p = 1 - q$, $p = 0.7$. $2pq = 0.42$.

10. Natural selection acts to promote the retention in the gene pool of only those allel that confer fitness on the individuals in the population. Unless changes in the forc of natural selection occur, any mutation in a gene most likely is going to reduce th fitness of those possessing it.

11. Mutation and the fact that it is not expressed in the phenotype of females heterozygous for the trait. They are "carriers" and there is not a strong selection pressur against the gene when it is present in carriers.

12. Reduced variability because of increased homozygosity.

13. Harmful, recessive alleles that have not affected the phenotype of heterozygous individuals will appear, through inbreeding, more frequently in the double dose and consequently exert their harmful effect in these homozygous individuals.

14. A group of actually or potentially interbreeding populations which ordinarily do n breed with other such groups even when there is opportunity to do so.

15. Those individuals in each generation of giraffes who because of their genetic make- grew necks slightly longer than those of their cousins would have been better able to forage in the branches of trees. Consequently, they would have been more likel to survive and to raise more young than their less well-endowed cousins. Because c their reproductory advantage, a larger proportion of the next generation would hav inherited the genes producing longer necks. This differs from Lamarck's explanati that it does not require that a mechanism exist for transmitting to sperm and eggs g netic information that has been modified by the activity of muscle cells, etc. in the giraffes' necks. Such a mechanism has never been demonstrated.

16. Interspecific competition is competition between individuals of different species fo some necessity of life such as food or shelter. Intraspecific competition is competi between the members of one species for the necessities of life.

hapter 33. The Struggle for Existence

Population growth can be studied in the laboratory and the resulting data compared ith the growth curve for an individual organism (studied in connection with Chapter 23). irect counts or turbidity measurements can be made on cultures of yeast cells started every 2 hours over the previous four days. Instructions are given in Exercise 27 of the laboratory anual. Serial dilutions and plating (as well as direct counts and turbidity measurements) an be used to determine the growth of populations of bacteria.

Additional laboratory work to accompany this chapter might include the isolation and ure culture of some bacterium, followed by a determination of its spectrum of antibiotic ensitivity (see Exercise 22 in the laboratory manual).

The film loops *Horntail Wasp*—Parts 1, 2, and 3 (Ealing #81-3337, #81-3345, and 81-3352) provide remarkable views of the life history of this insect and the behavior of wo of its parasites. Ealing also has a number of other film loops that illustrate examples of arasitism, predation, and cleaning symbiosis.

nswers to Exercises and Problems

1. (a) Phagocytosis in tissue space and inflammation,
   (b) Phagocytosis in lymph nodes,
   (c) Phagocytosis in liver and spleen,
   (d) Formation of antibodies.

2.

	Toxoid	Antitoxin
(a)	Toxin, extracted from culture, is weakened chemically.	Extracted from plasma of horse previously injected with tetanus antigen.
(b)	Elicits formation of antitetanus antibodies by antibody-producing machinery of body.	Directly inactivates tetanus toxin.
(c)	Before exposure to the disease.	After an unimmunized person is exposed to the disease.

3. The adult, sexually reproducing stage is found in us. The larval stage is found in the pig.
4. An internal parasite should not endanger the life of its host, must be able to find a mate with which to reproduce, and must be able to gain entrance into a new host. The pig tapeworm solves the first problem by its shape and the minimal demands it makes on its host. Hermaphroditism solves the second. Entry into a new host is facilitated by the enormous number of eggs it produces and the passing of its larval stage in pig muscle—a common food for man.

5. In every population of flies, a few individuals are present that have the gene or gene which produce an enzyme that degrades DDT rendering it harmless to them. Ordinarily the genes confer no selective advantage on their owners and the frequency of the gene does not increase. However, if DDT is added to the environment of the fly population, these genes become of great selective advantage. Their owners survive the applications of DDT while most flies without the genes do not. Those with the genes produce offspring out of proportion to their original numbers and the freque of the genes increases greatly in succeeding generations.
6. Birth rate (gestation period, litter size, age to sexual maturity, longevity) and death rate (availability of food, water, shelter, and the other necessities of life, degree of predation and parasitism, onset of aging – if that particular species does age and ha survived the other harmful forces).
7. Availability of food, water, shelter, and the other necessities of life, predation and parasitism; perhaps social factors.

Chapter 34. The Origin and Early Evolution of Life

It will be helpful if the student can observe closely a few specimens from each of th phyla discussed. Exercise 3 in the laboratory manual introduces the student to the anato and behavior of *Amoeba* and *Paramecium*. Film loops devoted to these organisms (*Amoe proteus* #81-5019, *Paramecium aurelia* #81-5027), as well as a number of other protists, are available from BFA Educational Media, 2211 Michigan Ave., Santa Monica, Californi 90404.

In answer to the question on p. 778, our present oceans probably do not contain a great a concentration of organic molecules as at the time life first arose because of the number of heterotrophs now present that consume them. Presumably, little or no abioti synthesis of organic molecules occurs.

Answers to Exercises and Problems

1. 2.5 gm.

$$(10 \xrightarrow{\text{4.5 billion years}} 5 \xrightarrow{\text{4.5 billion years}} 2.5)$$

2. Viruses are the simplest structures that contain the genetic information for their reproduction. They contain DNA (sometimes RNA), the same molecules that enco genetic information in all other organisms. The code "words" seem to be universal also. On the other hand, all viruses are obligate intracellular parasites. They can reproduce only when within living cells thus being unlikely candidates for the *first* form of life on earth.

3. No. It is virtually impossible to prove the negative of a proposition. Pasteur simply showed that all supposed cases of spontaneous generation were not valid. While there are several reasons for believing that the spontaneous generation of life does not occur on our earth anymore, there is no proof of this. There is simply no proof that it does occur.
4. The universality of DNA and the genetic code, RNA, ribosomes, unit membranes, proteins with only some two dozen of the many possible amino acides, cytochrome enzymes (with a few exceptions), and many other enzymes (including other enzymes that participate in cellular respiration).

Chapter 35. The Evolution of Plants

This chapter and the two that follow can perform a more important function than imply outlining phylogenetic relationships which are, often, exceedingly speculative. In a ook emphasizing the similarities of living things and organized on the basis of functions ather than phyla, there is a danger that an appreciation of the diversity of life will be iminished. In an effort to ameliorate this situation, the major phyla are now discussed not nly in the context of their likely phylogenetic relationships but, even more important, with mphasis on the structural and functional developments in each group that were to prove f major adaptive significance. These three chapters, then, can serve not only as a brief irvey of the major phyla but also as a review of the structural and functional adaptations scussed in the chapters of Parts III, IV, and V.

For Chapter 35, a display of representative plants would be helpful.

hapter 36. The Evolution of the Invertebrates

Many of the animals discussed will be familiar to the students even if their classifican is not. Specimens of species that are not likely to be familiar should be available. A de variety of animals are depicted in film loops available from BFA Educational Media, d their catalog should be consulted. In particular, their film loop *Peripatus* (Ealing 1-5969) gives students a chance to see living specimens of this important, but rare and isive, creature.

swers to Exercises and Problems

. (a) Aquatic, (b) Limited or none, (c) Awaits—more or less passively—the arrival of food.
. (a) Annelid, (b) Echinoderm, (c) Echinoderm, (d) Annelid, (e) Echinoderm.

3. The buoyancy of water provides greater physical support for their bodies than tha which workable legs could provide.
4. No. The virtually universal occurrence of cytochromes (which are also proteins wi the prosthetic group, heme) probably has provided the molecular precursor for th repeated evolution of hemoglobins.

Chapter 37. The Evolution of the Vertebrates

Answers to Exercises and Problems

1. Each group embodies adaptations that permitted it to leave the aquatic habitat of ancestors. In each case, the modifications – especially in regard to the continuing necessity of water for sexual reproduction – were not sufficient to free the group from dependence on water. The evolutionary history of the two groups differs in the plan of the amphibians gave rise to the reptiles and ultimately mammals and b while no other groups have evolved from the mosses. Also the amphibians were th *first* vertebrates to invade the land while the mosses evolved *after* the tracheophyt already had done so.
2. Feathers (warmth, waterproofing, streamlining, lightness, aerodynamic maneuver-ability), wings (escape from predators, rapid transport to suitable habitat), uric ac (low water need), single ovary and gonads which enlarge only during breeding sea (lightness), hollow bones (strength with lightness), air sacs (improved gas exchang cooling), no teeth (lightness), gizzard (replaces teeth), concentrated diet (high ene content with low mass), homeothermy (high metabolic rate independent of envir mental temperature), enlarged sternum and breast muscles (flying), laying of shell egg (lightness and protection from water loss by the embryo), flexible neck (perm rigid body, i.e. air frame), large cerebellum (efficient coordination and dynamic balance), reduced blood supply and living tissue in legs and feet (reduced heat los from these uninsulated structures), powerful heart (rapid circulation), no sweat gl (keeps feathers dry), thin, flat, ribs (strength and lightness coupled with efficient exchange), no ear lobes (streamlining), high blood sugar level (energy).
3. Waterproof skin, more efficient lungs, legs extend beneath the body rather than t sides, internal fertilization, shelled egg, uric acid excretion (in most), and larger b
4. That he is more closely related to man (*Homo sapiens*) than was formerly believe
5. No. The fossil record of species that seem to have given rise to adaptive radiation (e.g. early amphibians, reptiles) generally is scantier than that of species that have This suggests that the former were not as successful as the latter in their original h tat and presumably were less specialized.
6. None. His brain, however, is developed to a far greater extent than in any other primate.

7. No. Except for his brain, he has many mammalian features that should properly be considered primitive; that is, characteristic of the early mammals. His limbs, for example, resemble those of the first mammals much more closely than do those of such modern mammals as the pig and the bat. The whales don't even have anything more than vestiges of the hind limbs of their (and our) ancestors.
8. No. The earliest (and hence primitive) amphibians were the 4-legged descendants of the crossopterygians. The later loss of legs (among other things) that has occurred in the caecilians represents a recent specialization and not a primitive trait.

Glossary

In order to keep the glossary a practical size, few names of anatomical structures or names of taxa are included. The former are best described by pictures and these can be located through the index. The characteristics of and organisms in a given taxon can also be quickly located by referring to the index.

The system of diacritical marks indicating pronunciation is that used in the current edition of Webster's *New Collegiate Dictionary*, published by the G.&C. Merriam Co. The derivation of a word is given in cases where it may be of special interest or may be a mnemonic aid to the student.